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Alexander et al.

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(54) **ELECTRIC MACHINE ROTOR BAR AND METHOD OF MAKING SAME**

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H02K 19/14 (2006.01)

(52) **U.S. Cl.** **310/211**; 310/210; 310/215

(58) **Field of Classification Search** 310/211, 310/210, 215

See application file for complete search history.

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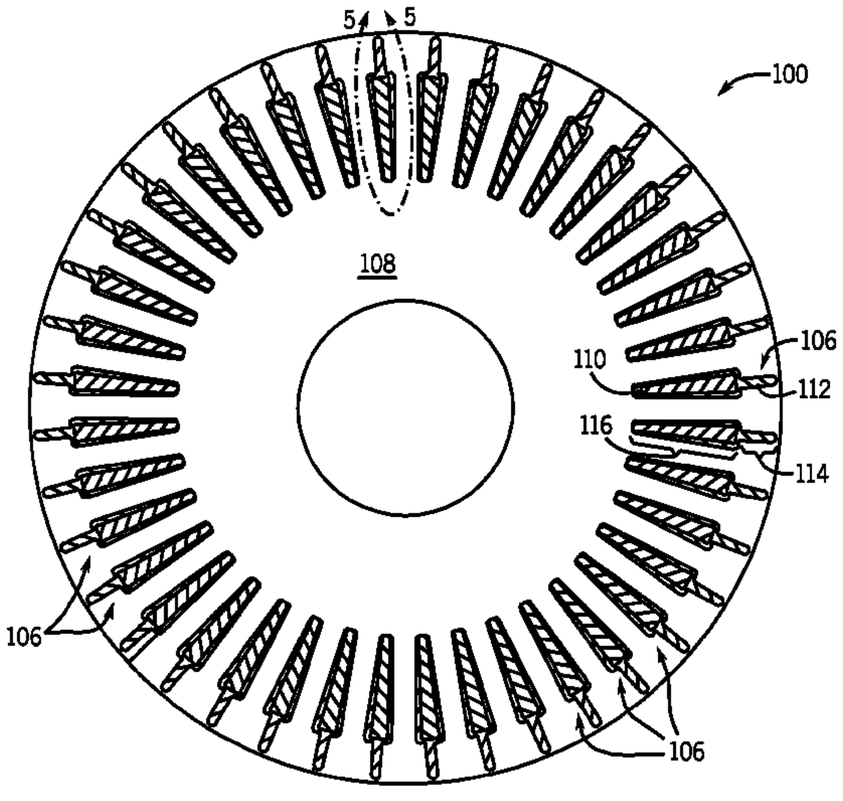
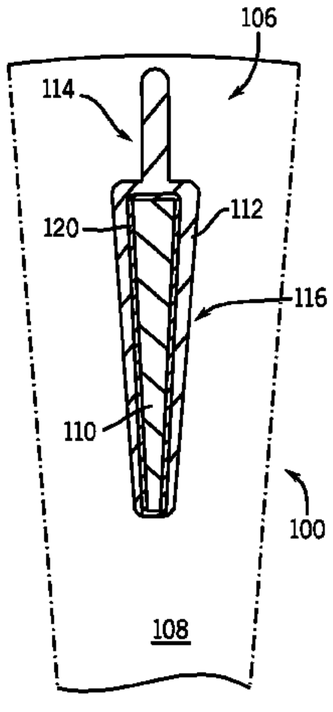
(57) **ABSTRACT**

A method, system, and apparatus including an electric machine having a plurality of rotor bars and a first coupling component configured to electrically couple the plurality of rotor bars together. Each rotor bar of the plurality of rotor bars includes a first metallic material having a first electrical resistivity and a second metallic material cast about the first material, where the second metallic material has a second electrical resistivity greater than the first electrical resistivity. The first metallic material has a first end and a second end opposite the first end and the first coupling component is coupled to the first end of the first metallic material.

16 Claims, 8 Drawing Sheets





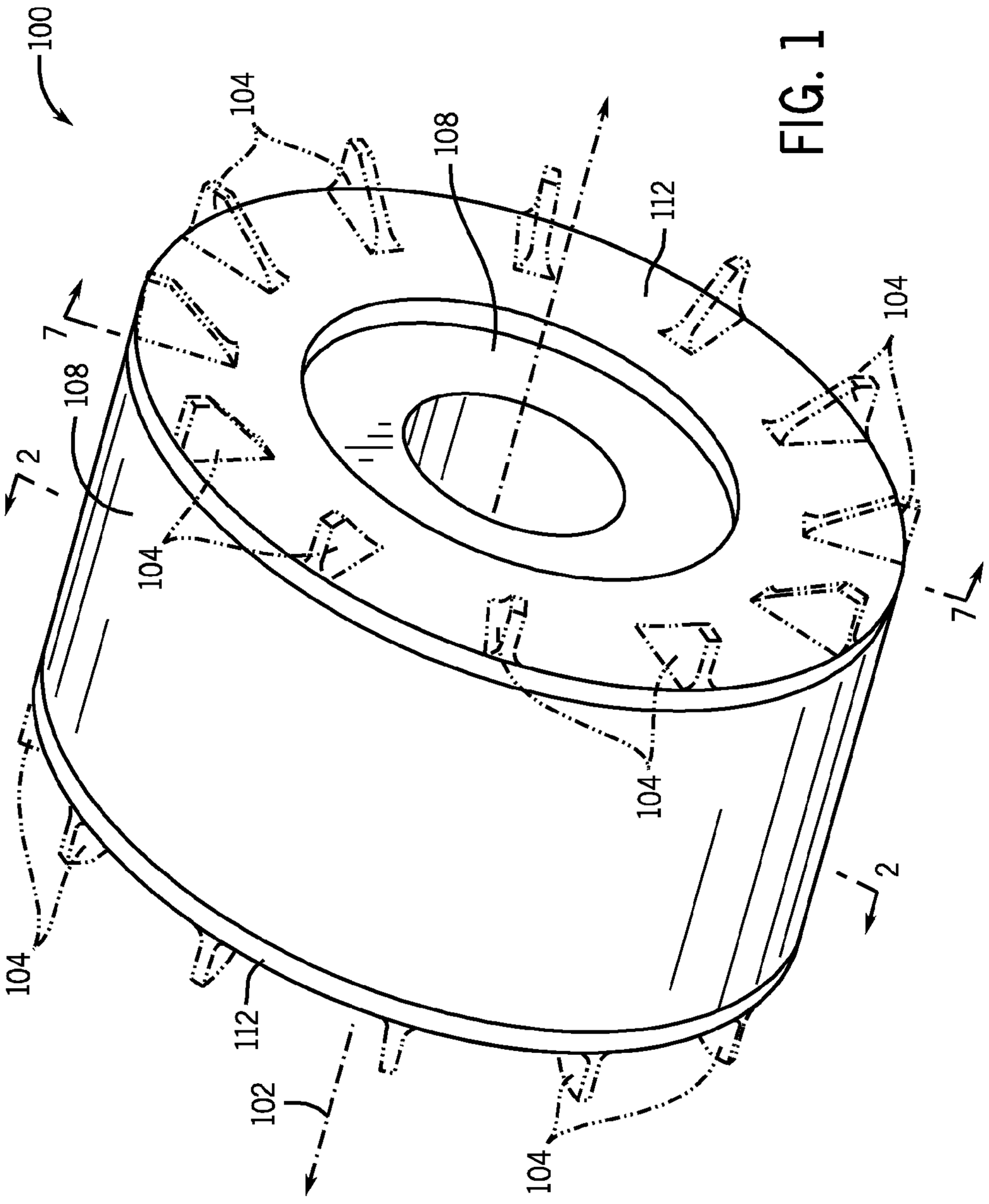


FIG. 1

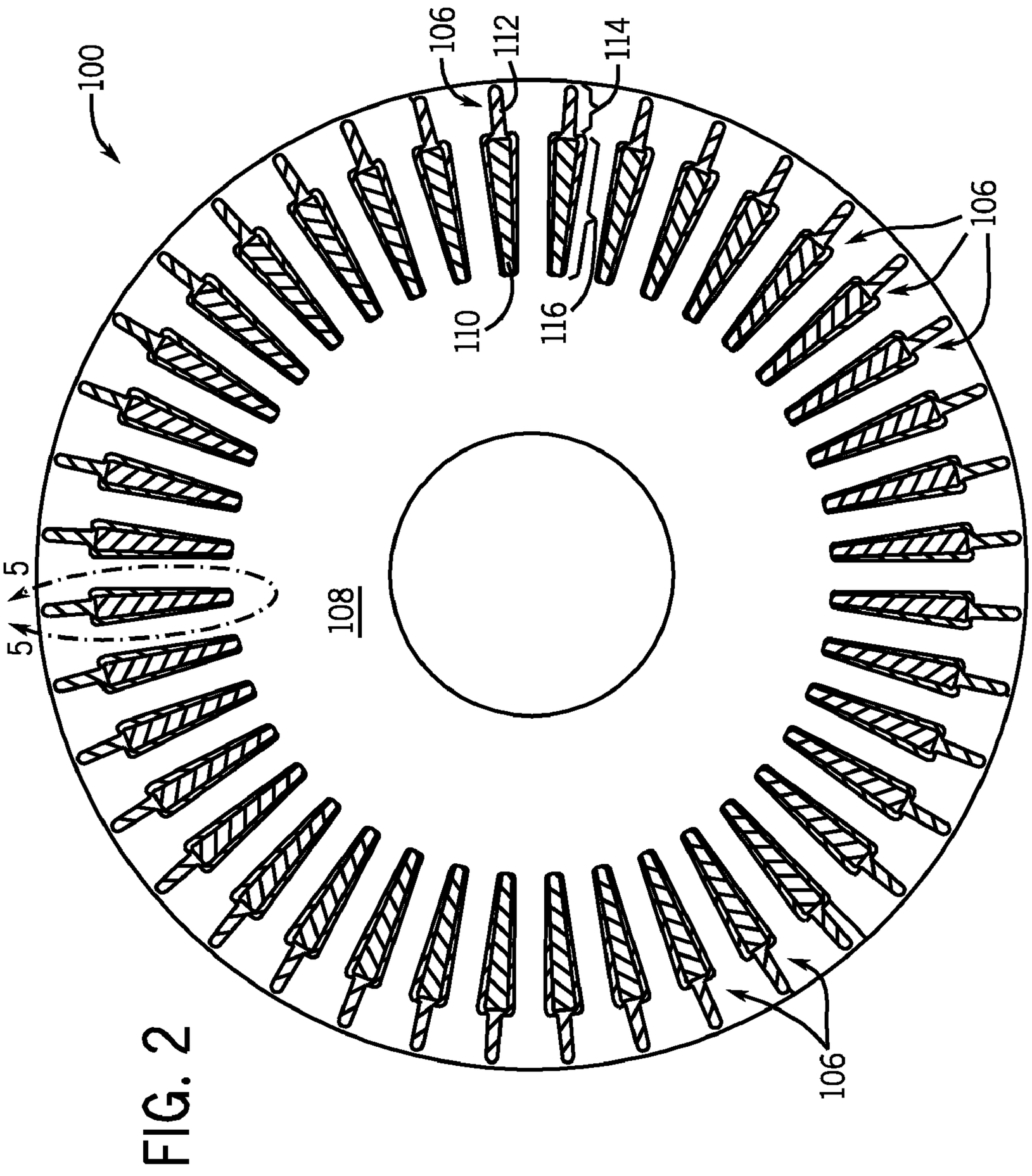


FIG. 2

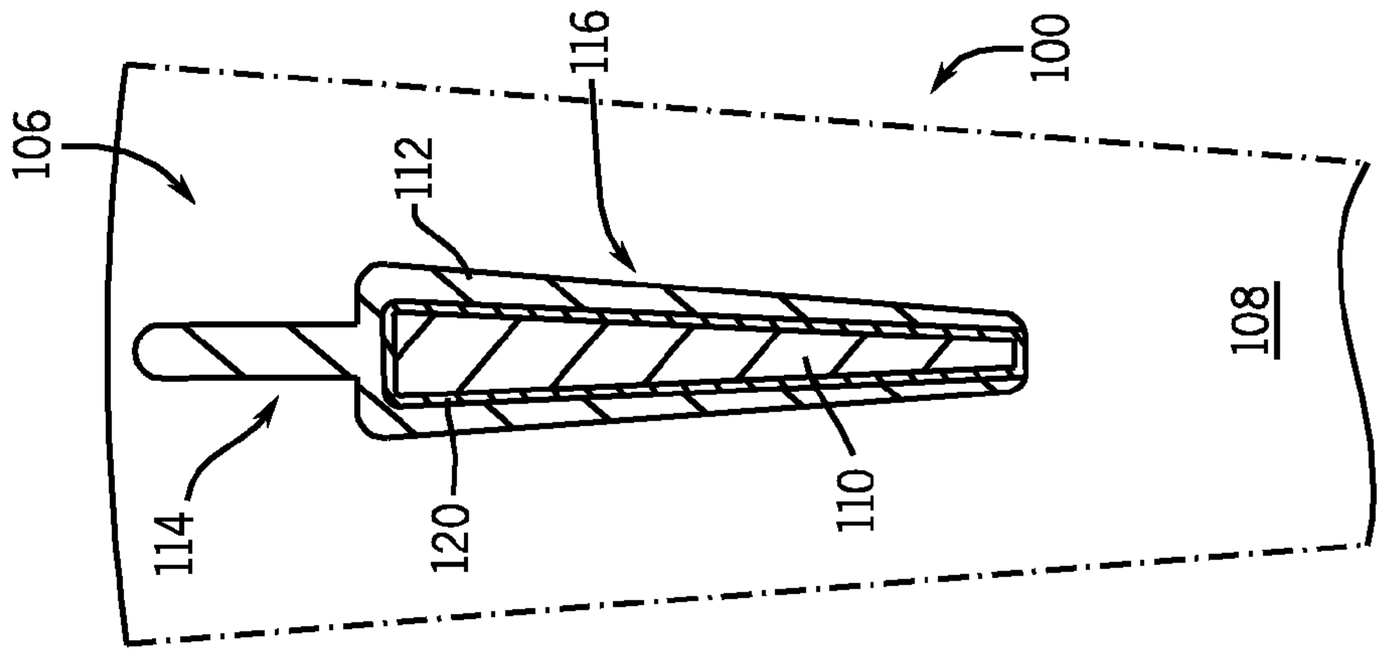


FIG. 5

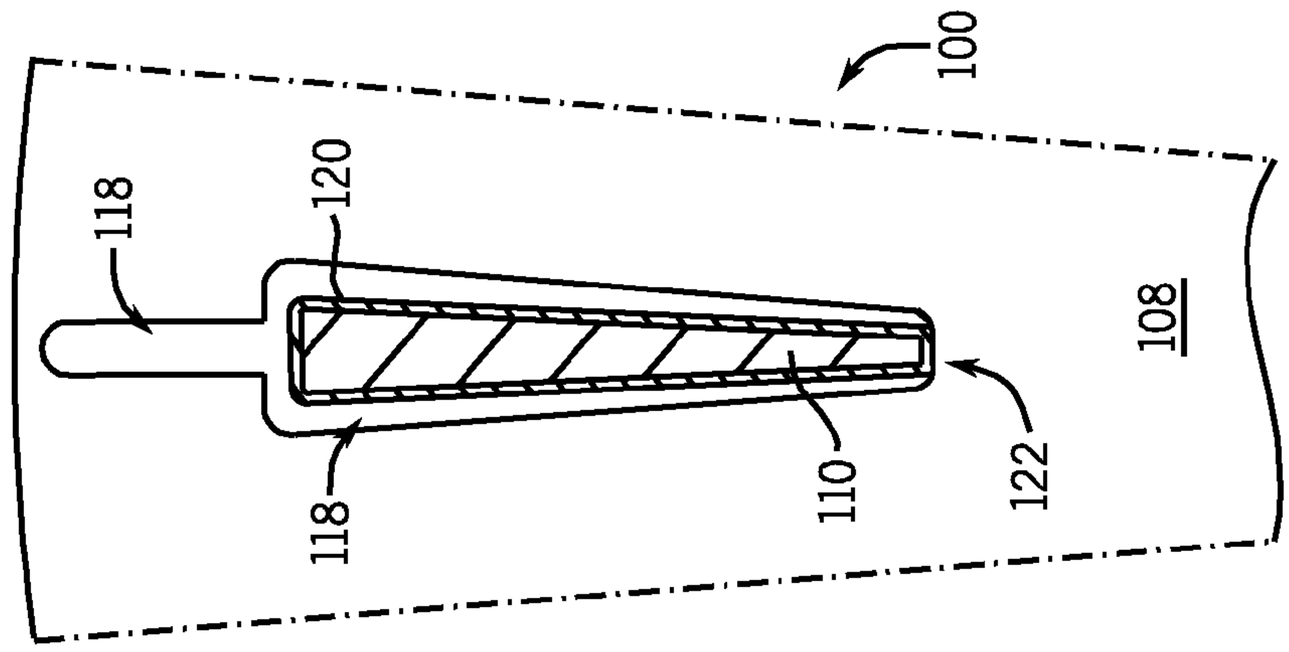


FIG. 4

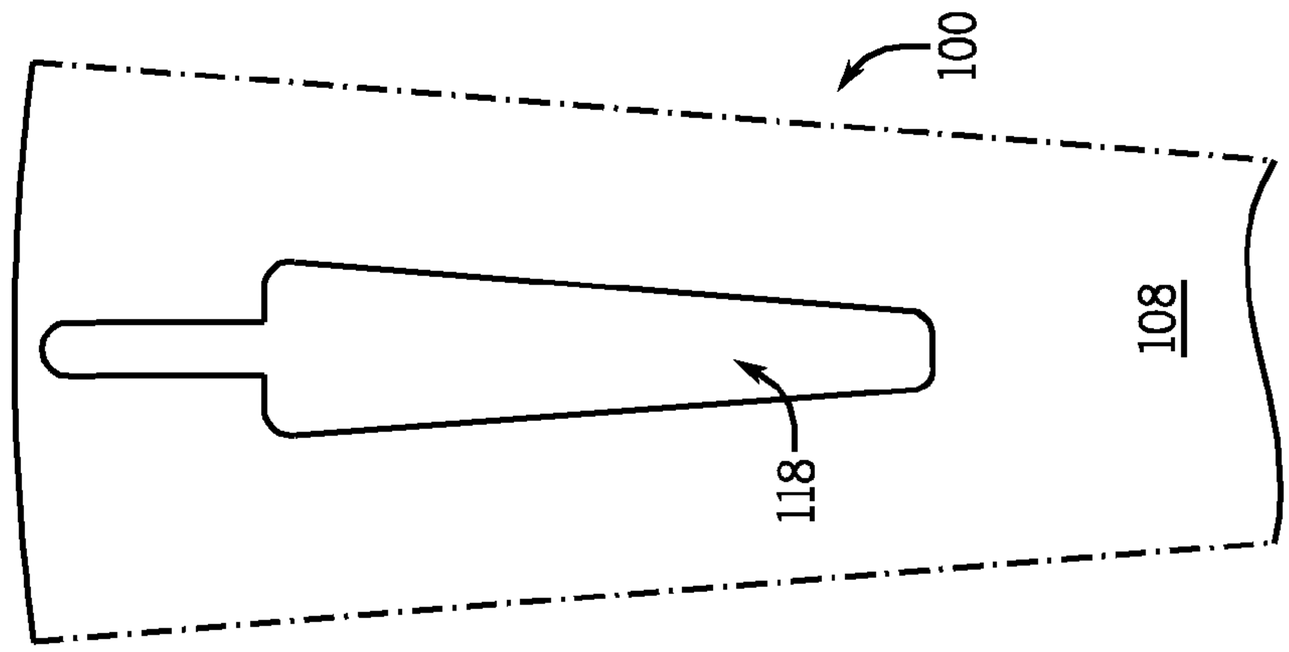


FIG. 3

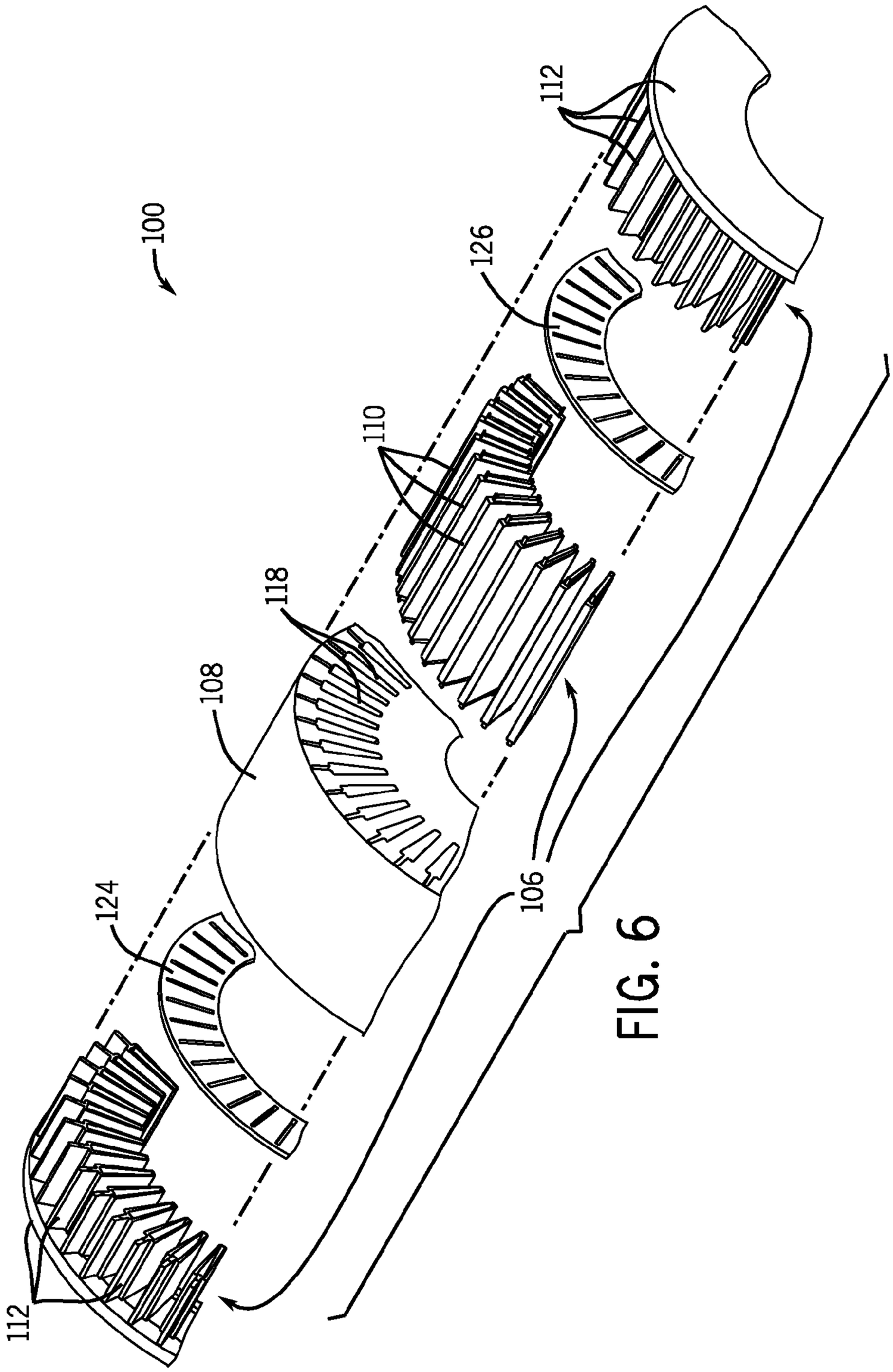
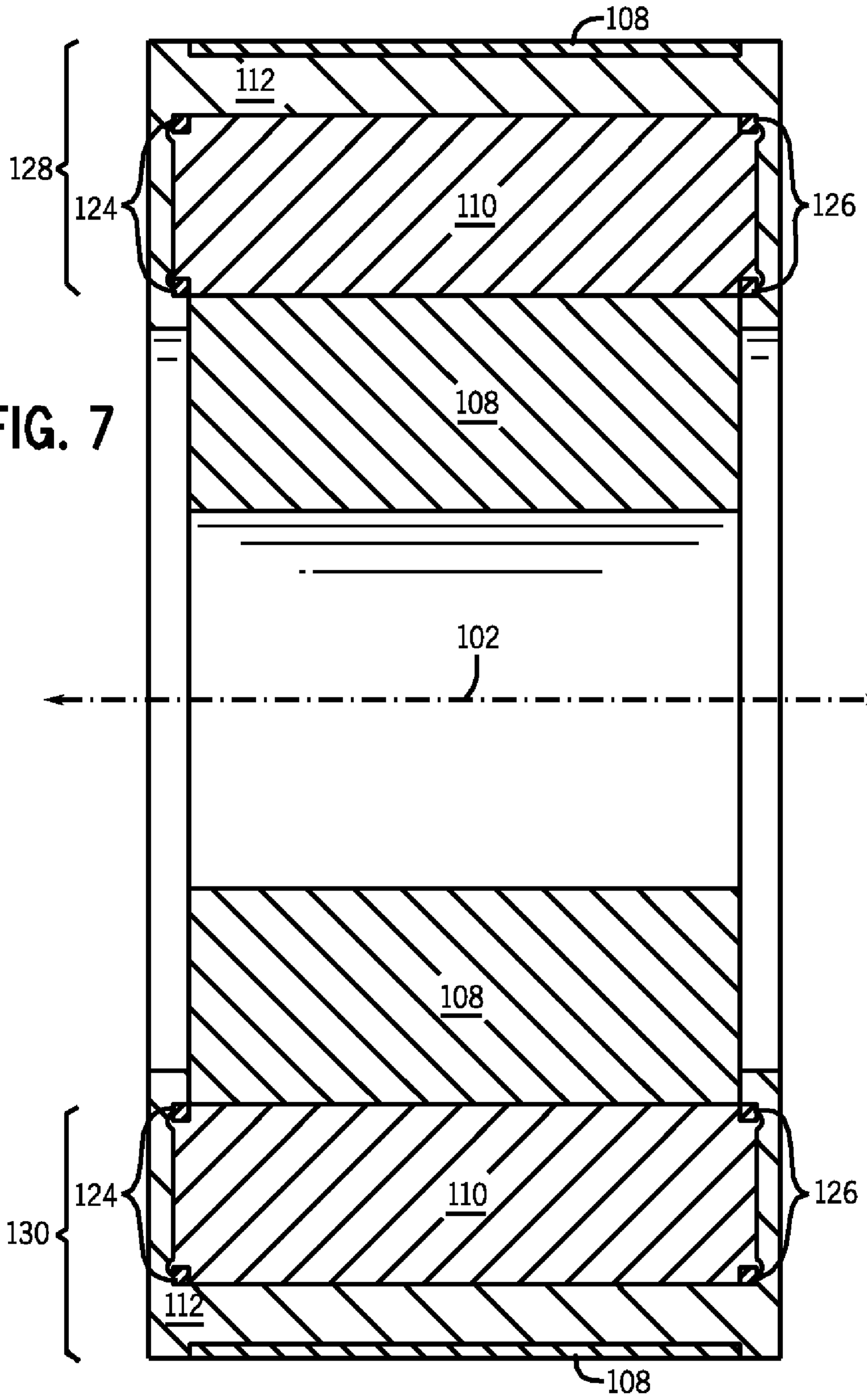


FIG. 6

FIG. 7



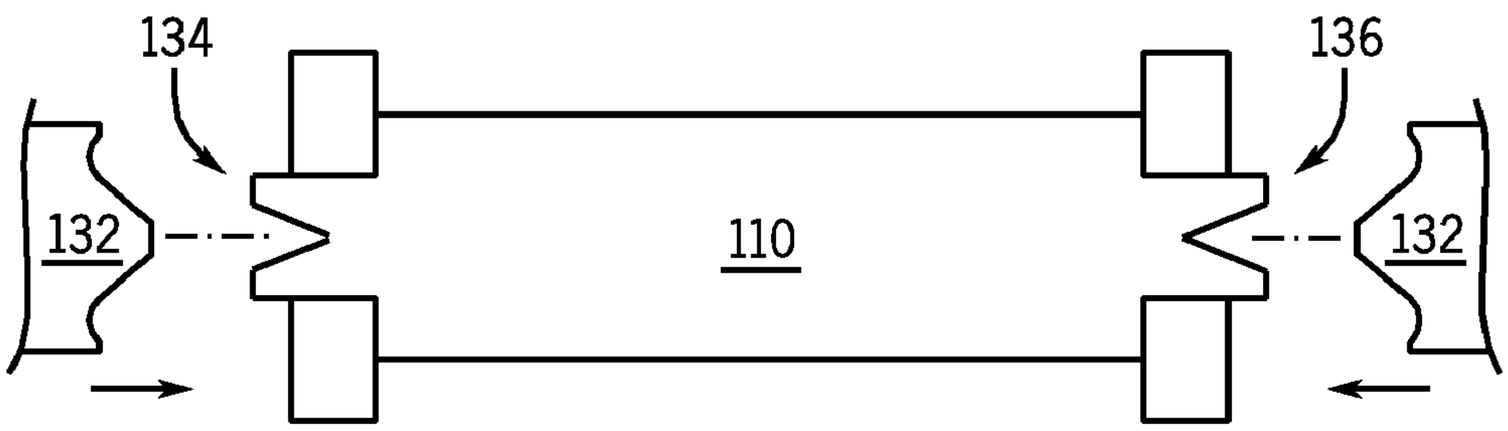


FIG. 8

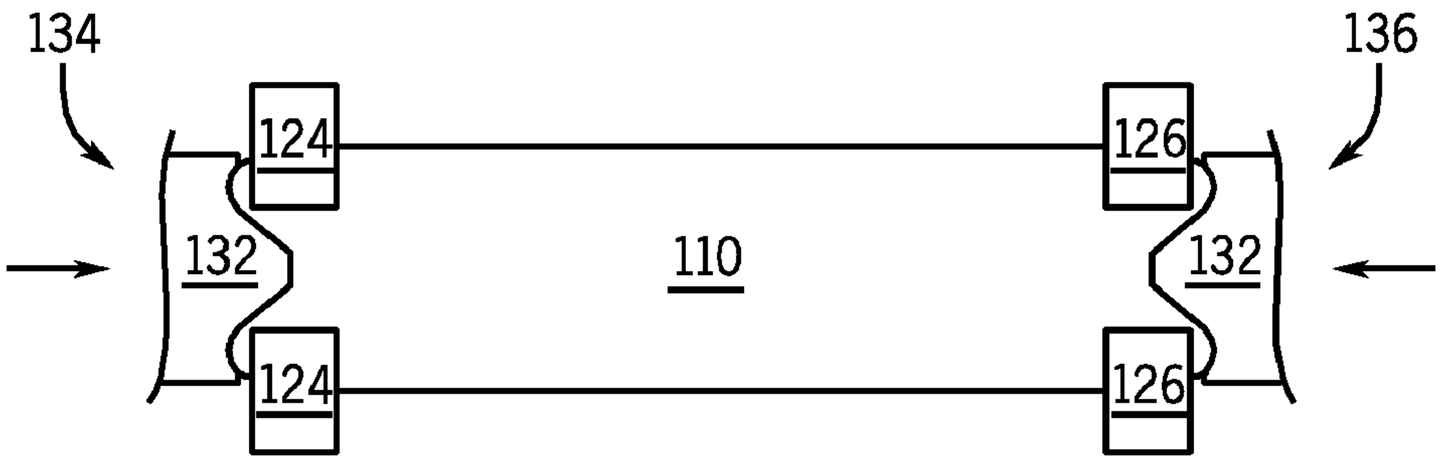


FIG. 9

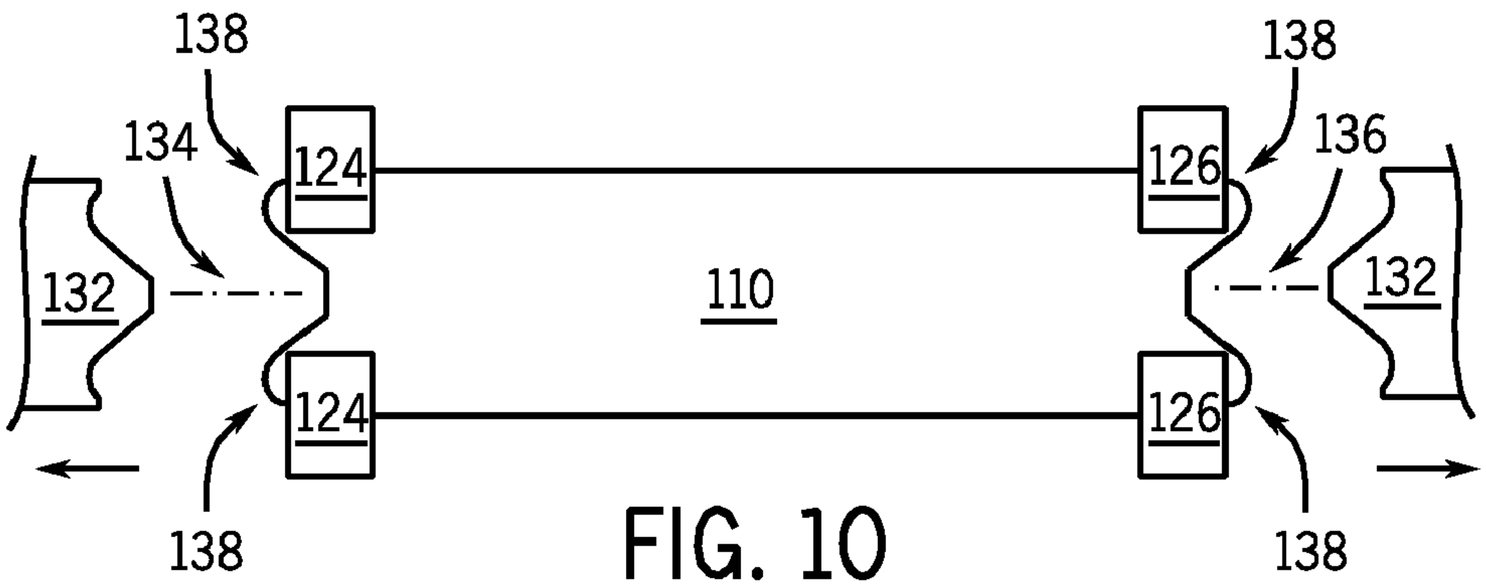


FIG. 10

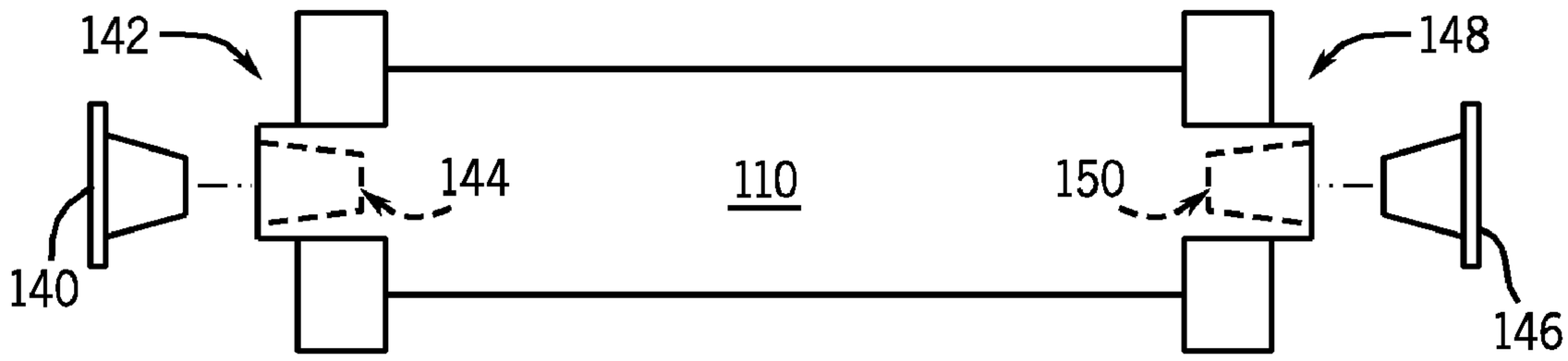

142
148
144
110
150
140
146

FIG. 11

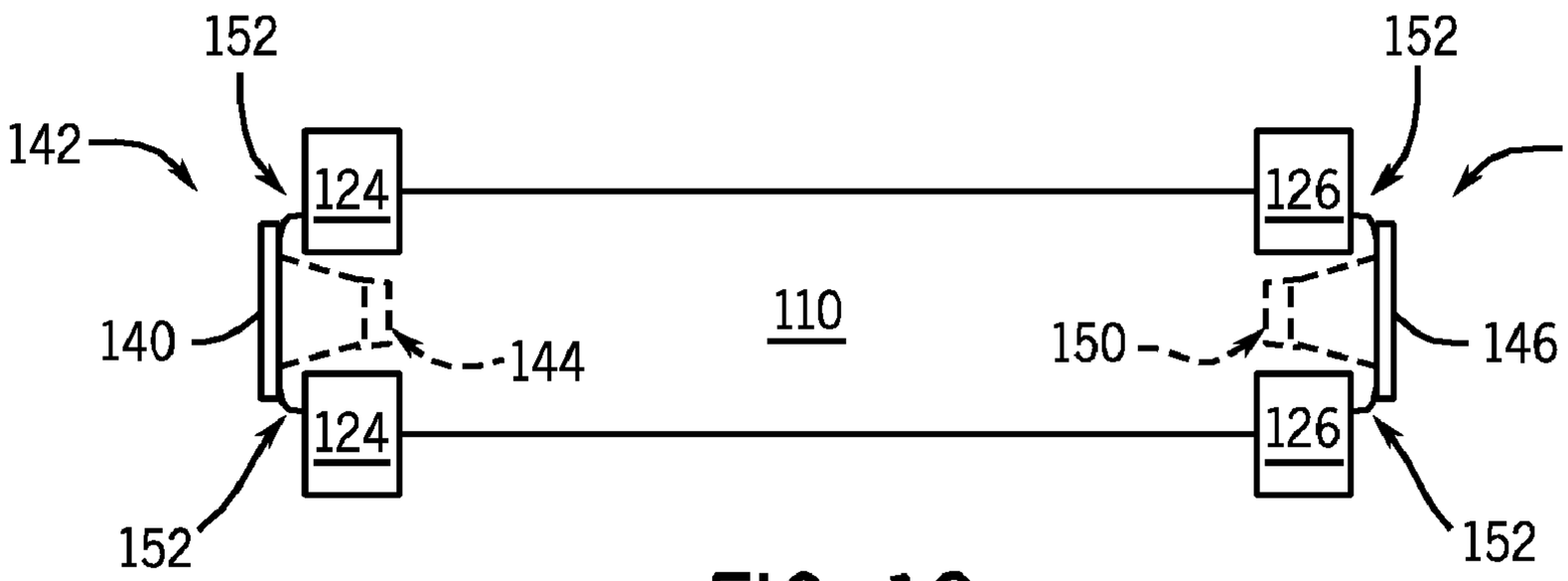

152
152
142
148
124
126
110
140
144
150
146
124
126
152
152

FIG. 12

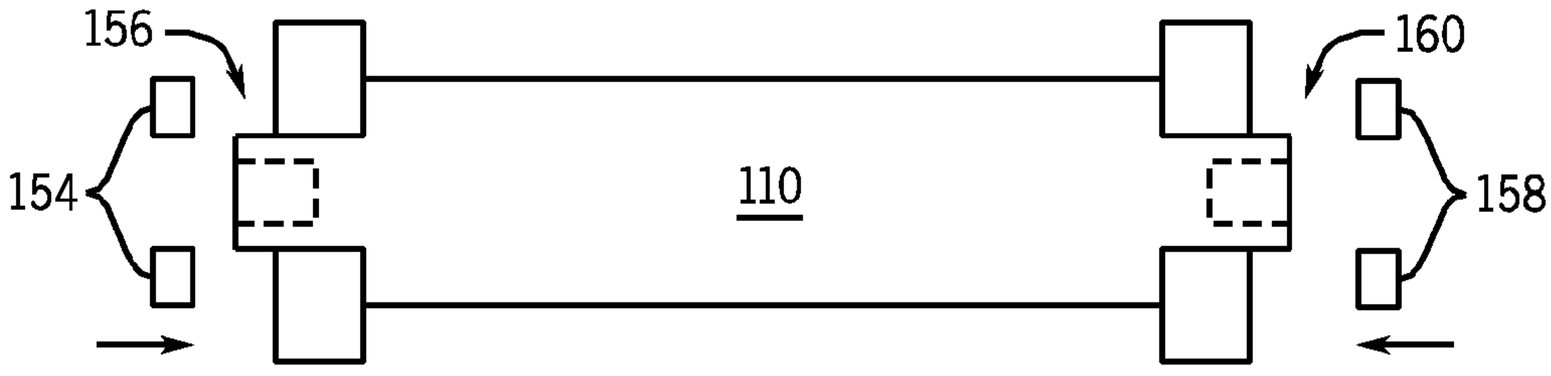


FIG. 13

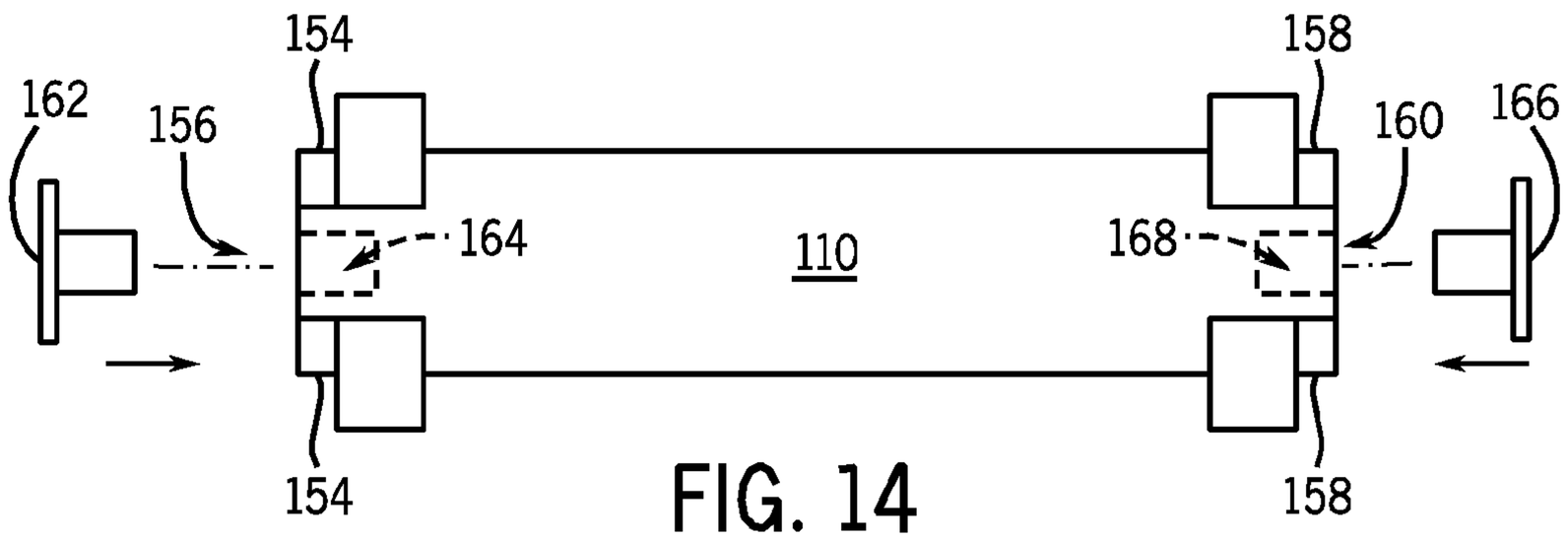


FIG. 14

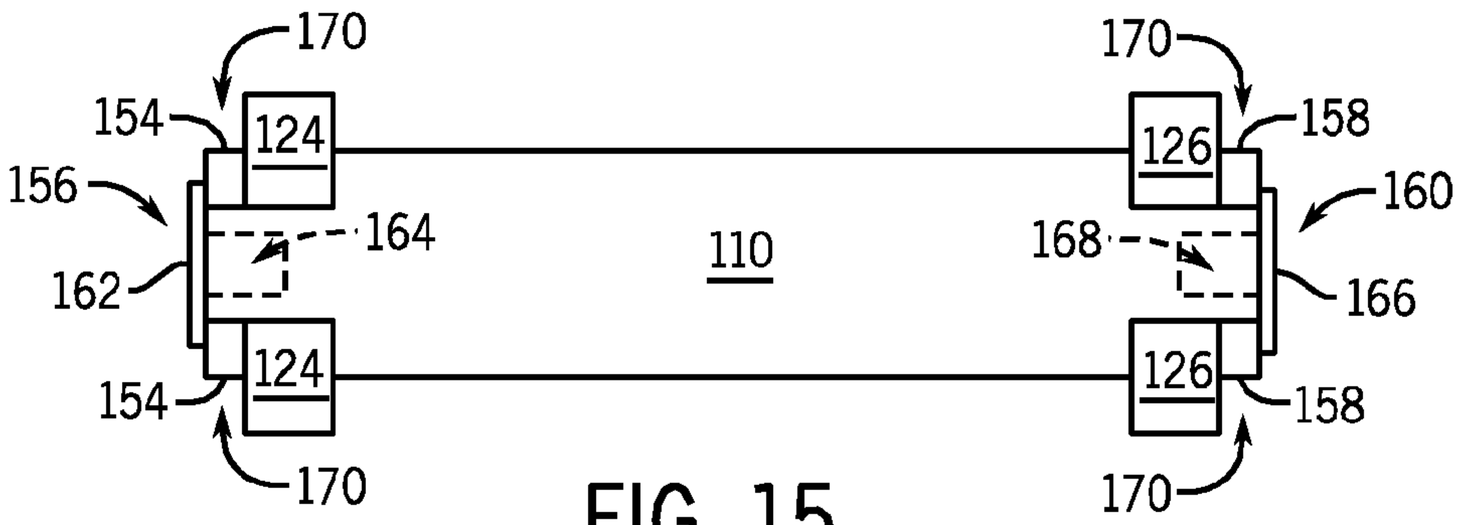


FIG. 15

ELECTRIC MACHINE ROTOR BAR AND METHOD OF MAKING SAME

BACKGROUND OF THE INVENTION

Embodiments of the invention relate generally to electric machine rotor bars and, more particularly, to a bi-metallic electric machine rotor bar.

Often, rotor bars of an electric machine such as an electric motor or generator are manufactured of one material. For example, rotor bars are often made of aluminum because of its electrical properties and the costs associated with "working" aluminum.

It has been found that the running efficiency of an electric machine can often be increased by decreasing the electrical resistance of the respective rotor bars. In other words, an electric machine having rotor bars with lower electrical resistance tends to operate more efficiently than a comparable electric machine having rotor bars with a higher electrical resistance (i.e., as rotor bar resistance decreases the electric machine running efficiency often increases).

To exploit this relationship between rotor bar resistance and running efficiency, rotor bars have been manufactured from materials having a lower electrical resistance than aluminum. For example, rotors bars made up of copper have been manufactured. However, due to the high melting point of copper, as compared to aluminum, and the difficulties associated with working with copper, copper rotor bars tend to be more costly than aluminum rotor bars.

It would therefore be desirable to provide an apparatus and method for cost effective manufacture of rotor bars that positively affect the running efficiency of an electric machine.

BRIEF DESCRIPTION OF THE INVENTION

In accordance with one aspect of the invention, an electric machine includes a plurality of rotor bars and a first coupling component configured to electrically couple the plurality of rotor bars together. Each rotor bar of the plurality of rotor bars includes a first metallic material having a first electrical resistivity and a second metallic material cast about the first material, where the second metallic material has a second electrical resistivity greater than the first electrical resistivity. The first metallic material has a first end and a second end opposite the first end and the first coupling component is coupled to the first end of the first metallic material.

In accordance with another aspect of the invention, a method of manufacturing an electric machine includes inserting a plurality of bars into a rotor bar housing and electrically coupling the plurality of bars together, where each bar of the plurality of bars includes a first metallic material having a first electrical resistivity. The method also includes casting a second metallic material about the plurality of bars inserted into the rotor bar housing, where the second metallic material has a second electrical resistivity greater than the first electrical resistivity.

In accordance with another aspect of the invention, an electric machine includes a plurality of rotor bars and a first electrical coupling ring configured to electrically couple each rotor bar of the plurality of rotor bars together. Each rotor bar of the plurality of rotor bars includes a metallic bar and a metallic covering surrounding at least a majority of the metallic bar. Each metallic bar includes a first material having a first electrical resistivity and each metallic covering has a second electrical resistivity greater than the first electrical resistivity.

Various other features and advantages will be made apparent from the following detailed description and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings illustrate embodiments presently contemplated for carrying out the invention.

In the drawings:

FIG. **1** is a diagram of an electric machine according to an embodiment of the invention.

FIG. **2** is a cross-sectional view of the electric machine of FIG. **1** according to an embodiment of the invention.

FIGS. **3-5** illustrate a portion of the electric machine of FIG. **2** and show an example of manufacturing a rotor bar according to an embodiment of the invention.

FIG. **6** is an exploded view of the electric machine of FIG. **1** according to an embodiment of the invention.

FIG. **7** is another cross-sectional view of the electric machine of FIG. **1** according to an embodiment of the invention.

FIGS. **8-10** illustrate securing a first metallic material of a rotor bar to a first ring and a second ring prior to the casting of a second metallic material of the rotor bar thereabout according to an embodiment of the invention.

FIGS. **11-12** illustrate securing a first metallic material of a rotor bar to a first ring and a second ring prior to the casting of a second metallic material of the rotor bar thereabout according to another embodiment of the invention.

FIGS. **13-15** illustrate securing a first metallic material of a rotor bar to a first ring and a second ring prior to the casting of a second metallic material of the rotor bar thereabout according to another embodiment of the invention.

DETAILED DESCRIPTION

Referring to FIG. **1**, a diagram a portion of an electric machine **100** is shown according to an embodiment of the invention. According to the embodiment of FIG. **1**, electric machine **100** has an axis of rotation **102** about which it rotates. Though not shown, but as would be appreciated by those skilled in the art, a shaft along axis of rotation **102** would, once rotated, cause electric machine **100** to rotate. It is contemplated that electric machine **100** may include a plurality of cooling fins **104** (shown in phantom). Embodiments without cooling fins **104** or with a greater or lower number of cooling fins than those shown in FIG. **1** are, however, envisioned.

It is also contemplated electric machine **100** may be of any type of electric machine that employs rotor bars. For example, such electric machines may include an induction machine such as an induction motor or generator. However, and more generally, such an electric machine may also include electric motors, generators, or the like. As will be shown below with respect to FIG. **2**, electric machine **100** includes a plurality of rotor bars.

Referring to FIG. **2**, a cross-sectional view of electric machine **100** along line **2-2** of FIG. **1** is shown according to an embodiment of the invention. Electric machine **100** includes a plurality of rotor bars **106** extending through a core material **108** (i.e., a rotor bar housing) of electric machine **100**, where each rotor bar of the plurality of rotor bars **106** includes at least a first metallic material **110** and a second metallic material **112**. First metallic material **110** has a first electrical resistivity, and second metallic material **112** has a second electrical resistivity greater than the first electrical resistivity. It is noted that each rotor bar **106** includes an upper portion **114** and a lower portion **116**.

According to an embodiment of the invention, first metallic material **110** includes a copper material (e.g., a copper bar) and/or a silver material while second metallic material **112** includes an aluminum material. It is envisioned, however, that first metallic material **110** may be constructed of a material other than copper or silver. For example, first metallic material **110** may be constructed of a first type of aluminum having a corresponding first electrical resistivity, and second metallic material **112** may be constructed of a second type of aluminum having a corresponding second electrical resistivity different from the first electrical resistivity. According to such an embodiment, the first type of aluminum of first metallic material **110** would have an electrical resistivity less than that of the second type of aluminum of second metallic material **112**. It is noted that second metallic material **112** may be constructed of a material other than aluminum.

According to the embodiment depicted in FIG. **2**, second metallic material **112** is a material cast about first metallic material **110**.

The running efficiency of electric machine **100** is generally more influenced by lower portion **116** of each rotor bar **106**. As electrical resistivity of lower portion **116** decreases, the running efficiency of electric machine **100** increases.

Further, starting torque of electric machine portion **100** may be influenced by upper portion **114** of each rotor bar **106**. For example, as the electrical resistivity of upper portion **114** increases, so may the starting torque. Such a scenario can arise when, for example, the electrical excitation is from a fixed frequency source such as line-starting from an AC 60 Hz source.

Embodiments of the invention aid in maximizing or at least increasing the running efficiency of an electric machine (e.g., electric machine **100**). Embodiments of the invention may also aid in increasing starting torque of an electric machine and/or limiting starting current of an electric machine. For example, the higher electrical resistivity of upper portion **114**, due to the higher electrical resistivity of second metallic material **112**, may increase starting torque and/or limit starting current. Further, since lower portion **116** includes first metallic material **110** having a lower electrical resistivity than second metallic material **112**, the running efficiency of a corresponding electric machine (e.g., electric machine **100**) increases.

Still referring to FIG. **2**, second metallic material **112** may be chosen to maximize or increase starting torque and/or limit starting current, while first metallic material **110** can be chosen to maximize or increase running efficiency. Again, the higher electrical resistivity of upper portion **114**, due to second metallic material **112**, may have a positive effect on the starting torque or starting current of electric machine **100**, while lower portion **116**, due to the lower electrical resistivity of first metallic material **110** of lower portion **116**, has a positive effect on the running efficiency of electric machine **100**.

As discussed above, it is contemplated that second material **112** may be cast about first material **110**. It is envisioned, however, that upper portion **114** of rotor bar **106** may be a preformed component. In such an embodiment, the preformed component may be constructed of the same material as second material **112**, or it may be constructed of another material. In either case, the preformed component has an electrical resistivity higher than the electrical resistivity of first material **110**.

It is also noted that embodiments of the invention may be employed to take advantage of the benefits of using high electrical resistivity rotor bars while reducing or limiting the manufacturing costs associated therewith. As would be appreciated by those skilled in the art, it is typically more expensive to manufacture an electric machine employing rotor bars made entirely of copper than to manufacture an electric machine that employs rotor bars made entirely of aluminum (i.e., a rotor bar typically having a higher electrical resistivity than a copper rotor bar). Such manufacturing cost differentials can be associated with the higher melting point of copper, which can necessitate more expensive tool and manufacturing processes. For example, it is often more expensive to cast copper than it is to cast aluminum.

According to embodiments of the invention, however, manufacturing costs of rotor bars that take advantage of the benefits of using materials with lower electrical resistivity such as copper can be minimized. For example, first metallic material **110** may be a pre-purchased copper bar either having the appropriate dimensions or may be machined to have the appropriate dimension, whereas second metallic material **112** may be cast about first metallic material **110**. Accordingly, the need to cast first metallic material **110** may be avoided.

FIGS. **3-5** illustrate a portion of electric machine **100** along line **5-5** of FIG. **2** and show an example of manufacturing a rotor bar according to an embodiment of the invention.

In FIG. **3**, an opening **118** in rotor core or housing **108** for insertion and casting of the rotor bar components is shown. In FIG. **4**, opening **118** is shown with a first metallic material **110** inserted therein. It is contemplated that first metallic material **110** may be a bar or bar-like material. As shown, it is contemplated that first metallic material **110** may have an intervening material **120** thereon. Intervening material **120** may be a cladding (e.g., an aluminum, nickel, or other type of cladding). It is also contemplated that intervening material **120** may be an insulating material. It is noted, however, that embodiments free of an intervening material are also contemplated. Further details regarding intervening material **120** will be set forth below with respect to FIG. **5**.

FIG. **5** illustrates that cast material **112** (i.e., second metallic material) fills the remaining void of opening **118** and is cast about first metallic material **110** and about intervening material **120** if present. If present, intervening material **120** may be an electrical insulator configured to at least partially electrically isolate cast material **112** from first material **110**. In addition, or alternatively, intervening material **120** may be a cladding (e.g., an aluminum cladding) configured to enhance adhesion or coupling between first material **110** and cast material **112**. As explained above with respect to FIG. **4**, embodiments free of intervening material **120** are contemplated. Accordingly, with or without intervening material **120** shown in FIG. **5**, cast material **112** about first metallic material **110** forms rotor bar **106**.

It is noted that cast material **112** of rotor bar **106** need not entirely cover first material **110**. For example, as depicted in the embodiment of FIG. **4**, a bottom portion **122** of first material **110**/intervening material **120** combination is adjacent to rotor core **108** without cast material **112** therebetween. Accordingly, casting material **112** can either fully or partially surround first material insert **110** depending on the location of first material **110** within opening **118**.

As shown in FIG. **5**, rotor bar **106** includes upper portion **114** and lower portion **116**. First metallic material **110** has a lower electrical resistance than cast material **112**. Accordingly, the effective electrical resistance of lower portion **116** is lower than the effective electrical resistance of upper portion **114**. Due to the lower effective electrical resistance of lower portion **116**, electric machine **100** will have a higher running efficiency than a comparable electric machine (not shown) that employs rotor bars containing only cast material **112**.

Further, since cast material **112** in upper portion **114** has a higher electrical resistance than first metallic material **110**, electric machine **100** may have a higher starting torque than a comparable machine (not shown) that employs rotor bars containing only the material employed for first metallic material **110** (e.g., copper). Further, the configuration of rotor bar **106** may also be beneficial in limiting starting current.

Due to the bi-metallic nature of rotor bar **106**, electric machine **100** may benefit from the higher electrical resistance properties of cast material **112** while also benefiting from the lower electrical resistance properties of first metallic material **110**

Referring now to FIG. **6**, an exploded view of a portion of electric machine **100** of FIG. **1** is shown according to an embodiment of the invention. It is noted that fins **104** of FIG. **1** are not shown. As shown in FIG. **6**, electric machine **100** includes a first coupling component **124** (i.e., a first ring), rotor core **108** having openings **118** therein, and a second coupling component **126** (i.e., a second ring). The plurality of rotor bars **106** are also shown in an exploded view, where each rotor bar **106** includes a first metallic material **110** and a second metallic material **112**. It is noted that second metallic material **112** is shown as two components (i.e., one component next to first ring **124** and another component next to second ring **126**) for illustrative purposes. According to embodiments where second metallic material **112** is cast about first metallic material **110**, second metallic material **112** is one component.

Though not shown, it is contemplated that first metallic material **110** may have an intervening material (e.g., intervening material **120** of FIGS. **4-5**) coupled thereto. If the intervening material is an insulator, first and second coupling components **124**, **126** would also be substantially encased in the insulating material such that first metallic material **110** and first and second coupling components **124**, **126** are electrically coupled together but substantially electrically isolated from second metallic material **112**.

As explained above with respect to FIGS. **2-5**, according to embodiments of the invention, first metallic material **110** has a lower electrical resistance than second metallic material **112**. First metallic material **110** may be a bar or bar-like material, which is placed in an opening **118**. According to an embodiment, once each metallic material **110** is placed in each opening **118**, first and second coupling components **124**, **126** are coupled thereto. Though first and second coupling components **124**, **126** are shown as being circular or ring-shaped in the embodiment depicted in FIG. **6**, other shapes are contemplated.

Still referring to FIG. **6**, second metallic material **112** may be cast around first metallic material **110** into opening **118**. As such, the manufacturing costs associated with casting first metallic material **110** may be avoided since first metallic material **110** need not be cast. According to the embodiments depicted in FIGS. **1** and **6**, second metallic material **112** is also cast about first and second coupling components **124**, **126**.

Referring now to FIG. **7**, a cross-sectional view of electric machine **100** along line **7-7** of FIG. **1** is shown according to an embodiment of the invention. A first rotor bar **128** and a second rotor bar **130** are shown in FIG. **7**, where each rotor bar **128**, **130** includes first metallic material **110** and a second metallic material **112**. Also shown in FIG. **7** are first ring **124** (i.e., a first coupling component) and second ring **126** (i.e., a second coupling component), where each ring **124**, **126** electrically couples first and second rotor bars **128**, **130** to the other rotors bars (not shown) positioned about the circumference of electric machine **100**. It is contemplated that first and second rings **124**, **126** may be brazed to first material **110** to enable or enhance the electric coupling therebetween.

It is noted that the embodiment of electric machine **100** shown in FIG. **7** does not include cooling fins (e.g., cooling fins **104** of FIG. **1**). However, as suggested in the description of FIG. **1**, embodiments of an electric machine, such as electric machine **100**, having cooling fins are contemplated.

FIGS. **8-10** show steps for securing first metallic material **110** to first ring **124** and second ring **126** prior to the casting of second metallic material **112** thereabout according to an embodiment of the invention.

In FIG. **8**, a compression tool **132** is aligned with a first end **134** and a second end **136** of first metallic material **110**. In FIG. **9**, compression tool **132** applies pressure to first and second ends **134**, **136**, thus deforming first and second ends **134**, **136** such that they overlap a portion of a first ring **124** and a portion of a second ring **126**, respectively. As shown in FIG. **10**, compression tool **132** is removed from deformed first and second ends **134**, **136**, thus leaving a low resistance contact **138** formed between first metallic material **110** and first and second rings **124**, **126**. The low resistance contacts **138** thus formed ensure that first and second rings **124**, **126** electrically couple all rotor bars **106** together as described above.

FIGS. **11-12** show steps for securing first metallic material **110** to first ring **124** and second ring **126** prior to the casting of second metallic material **112** thereabout according to another embodiment of the invention.

In FIG. **11**, a first screw cap **140** is aligned with a first end **142** of a first metallic material **110**, which has a first cavity **144** formed therein, and a second screw cap **146** is aligned with a second end **148** of first metallic material **110**, which has a second cavity **150** formed therein. In FIG. **12**, first and second screw caps **140**, **146** are screwed into first and second cavities **144**, **150** of first metallic material **110**, thus causing first metallic material **110** to overlap first ring **124** and second ring **126**. As such, a low resistance contact **152** is formed between first metallic material **110** and first and second rings **124**, **126**. In this manner, the low resistance contacts **152** thus formed ensure that first and second rings **124**, **126** electrically couple all rotor bars **106** together as described above.

According to one embodiment, second metallic material **112** is cast around first metallic material **110** and first and second rings **124**, **126** with first and second screw caps **140**, **146** left inserted into first metallic material **110**. In this manner, second metallic material **112** is cast around first and second screw caps **140**, **146**. According to another embodiment, first and second screw caps **140**, **146** may be removed prior to casting.

FIGS. **13-15** show steps for securing first metallic material **110** to first ring **124** and second ring **126** prior to the casting of second metallic material **112** thereabout according to another embodiment of the invention.

In FIG. **13**, a first washer **154** is aligned with a first end **156** of first metallic material **110**, and a second washer **158** is aligned with a second end **160** of first metallic material **110** opposite first end **156**. In FIG. **14**, first washer **154** is positioned about first end **156**, and second washer **158** is positioned about second end **160**. In addition, a first screw cap **162** is aligned with first end **156** of first material **110**, which has a first cavity **164** formed therein, and a second screw cap **166** is aligned with second end **160** of first material **110**, which has a second cavity **168** formed therein. As shown in FIG. **15**, first screw cap **162** is coupled to first end **156** and second screw cap **166** is coupled to second end **160**. As such, first metallic material **110** makes a low resistance contact **170** with first

ring **124** via first screw cap **162** and first washer **154** and with second ring **126** via second screw cap **166** and second washer **158**.

Therefore, according to one embodiment of the invention, an electric machine includes a plurality of rotor bars and a first coupling component configured to electrically couple the plurality of rotor bars together. Each rotor bar of the plurality of rotor bars includes a first metallic material having a first electrical resistivity and a second metallic material cast about the first material, where the second metallic material has a second electrical resistivity greater than the first electrical resistivity. The first metallic material has a first end and a second end opposite the first end and the first coupling component is coupled to the first end of the first metallic material.

According to another embodiment of the invention, a method of manufacturing an electric machine includes inserting a plurality of bars into a rotor bar housing and electrically coupling the plurality of bars together, where each bar of the plurality of bars includes a first metallic material having a first electrical resistivity. The method also includes casting a second metallic material about the plurality of bars inserted into the rotor bar housing, where the second metallic material has a second electrical resistivity greater than the first electrical resistivity.

According to another embodiment of the invention, an electric machine includes a plurality of rotor bars and a first electrical coupling ring configured to electrically couple each rotor bar of the plurality of rotor bars together. Each rotor bar of the plurality of rotor bars includes a metallic bar and a metallic covering surrounding at least a majority of the metallic bar. Each metallic bar includes a first material having a first electrical resistivity and each metallic covering has a second electrical resistivity greater than the first electrical resistivity.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. An electric machine comprising:

a plurality of rotor bars;

a first coupling component configured to electrically couple the plurality of rotor bars together, wherein each rotor bar of the plurality of rotor bars comprises:

a first metallic material having a first electrical resistivity, the first metallic material having a first end and a second end opposite the first end, wherein the first coupling component is coupled to the first end of the first metallic material; and

a second metallic material cast about the first material and about portions of the first coupling component and having a second electrical resistivity greater than the first electrical resistivity;

wherein the first metallic material comprises a copper bar and the second metallic material comprises aluminum;

wherein each rotor bar of the plurality of rotor bars has a first end and a second end opposite the first end, and wherein the first coupling component is electrically coupled to the first end of each rotor bar of the plurality of rotor bars;

wherein the electric machine further comprises a second coupling component coupled to the second end of each rotor bar of the plurality of rotor bars, wherein the second coupling component is configured to electrically couple the plurality of rotor bars together; and

wherein the second metallic material is also cast about portions of the second coupling component.

2. The electric machine of claim **1** further comprising:

a first cap screwed to a first end of the first metallic material; and

a second cap screwed to a second end of the first metallic material opposite the first end of the first metallic material.

3. The electric machine of claim **1** wherein each rotor bar of the plurality of rotor bars further comprises an intervening material between the first and second metallic materials, wherein the intervening material is configured to aid in an adhesion of the second metallic material to the first metallic material.

4. The electric machine of claim **3** wherein the intervening material comprises an aluminum cladding over the first metallic material.

5. The electric machine of claim **1** further comprising an intervening material coupled to the first material of each rotor and to the first and second coupling components, and wherein the intervening material is configured to at least partially electrically isolate the first metallic material of each rotor bar and the first and second coupling components from the second material of each rotor bar.

6. A method of manufacturing an electric machine comprising:

inserting a plurality of bars into a rotor bar housing, wherein each bar of the plurality of bars comprises a first metallic material having a first electrical resistivity;

coupling a first coupling component to the plurality of bars to electrically couple the plurality of bars together; and

casting a second metallic material about the plurality of bars inserted into the rotor bar housing and about portions of the first coupling component, wherein the second metallic material has a second electrical resistivity greater than the first electrical resistivity;

wherein electrically coupling the plurality of bars together comprises:

coupling a first coupling component to a first end of each bar of the plurality of bars; and

coupling a second coupling component to a second end of each bar of the plurality of bars opposite the first end; and

wherein coupling the first coupling component to a first end of each bar of the plurality of bars comprises:

compressing the first end of each bar of the plurality of bars such that a first portion of each bar of the plurality of bars deforms to overlap a portion of the first coupling component; and

compressing the second end of each bar of the plurality of bars such that a second portion of each bar of the plurality of bars deforms to overlap a portion of the second coupling component.

7. The method of claim **6** further comprising coupling an electrical insulator to each bar of the plurality of bars.

8. The method of claim **6** further comprising cladding each bar of the plurality of bars with a metallic cladding material.

9. The method of claim **8** wherein the cladding material comprises aluminum.

10. The method of claim **6** wherein coupling a first coupling component to a first end of each bar of the plurality of bars comprises brazing the first coupling component to the

first end of each bar of the plurality of bars, and wherein coupling a second coupling component to a second end of each bar of the plurality of bars opposite the first end comprises brazing the second coupling component to the second end of each bar of the plurality of bars.

11. An electric machine comprising:

a plurality of rotor bars;

a first electrical coupling ring configured to electrically couple each rotor bar of the plurality of rotor bars together, wherein each rotor bar of the plurality of rotor bars comprises:

a metallic bar comprising a first material having a first electrical resistivity; and

a metallic covering surrounding at least a majority of the metallic bar, the metallic covering casted to the metallic bar and having a second electrical resistivity greater than the first electrical resistivity;

a second electrical coupling ring configured to electrically couple each rotor bar of the plurality of rotor bars together; and

an insulating material coupled to the first and second coupling rings and to the metallic bar of each rotor bar, wherein the insulating material is configured to at least partially isolate the first and second coupling rings and the metallic bar of each rotor bar form the metallic covering of each rotor bar.

12. The electric machine of claim **11** wherein each rotor bar of the plurality of rotor bars further comprises a cladding configured to enhance bonding between the metallic covering and the metallic bar component.

13. The electric machine of claim **12** wherein the cladding comprises aluminum and the metallic bar comprises at least one of copper, nickel, and silver.

14. The electric machine of claim **11** wherein the metallic covering comprises aluminum.

15. An electric machine comprising:

a plurality of rotor bars;

a first electrical coupling ring configured to electrically couple each rotor bar of the plurality of rotor bars together, wherein each rotor bar of the plurality of rotor bars comprises:

a metallic bar comprising a first material having a first electrical resistivity and comprising a first end and a second end opposite the first end;

a metallic covering surrounding at least a majority of the metallic bar, the metallic covering having a second electrical resistivity greater than the first electrical resistivity;

a first screw cap coupled to the first end of the metallic bar; and

a washer component about the first end of the metallic bar and positioned adjacent to a portion of the first screw cap and the first electrical coupling ring, wherein the metallic bar is electrically coupled to the first electrical coupling ring via the portion of the first screw cap and the washer component.

16. A method of manufacturing an electric machine comprising:

inserting a plurality of bars into a rotor bar housing, wherein each bar of the plurality of bars comprises a first metallic material having a first electrical resistivity;

electrically coupling the plurality of bars together;

casting a second metallic material about the plurality of bars inserted into the rotor bar housing, wherein the second metallic material has a second electrical resistivity greater than the first electrical resistivity;

wherein electrically coupling the plurality of bars together comprises:

coupling a first coupling component to a first end of each bar of the plurality of bars; and

coupling a second coupling component to a second end of each bar of the plurality of bars opposite the first end; and

wherein coupling the first coupling component to a first end of each bar of the plurality of bars comprises:

compressing the first end of each bar of the plurality of bars such that a first portion of each bar of the plurality of bars deforms to overlap a portion of the first coupling component; and

compressing the second end of each bar of the plurality of bars such that a second portion of each bar of the plurality of bars deforms to overlap a portion of the second coupling component.

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